Poster #02

Prediction of Global Geomagnetic Fied Disturbances using Recurrent Neural Network

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MAGICIAN Team for Forecasting GICs

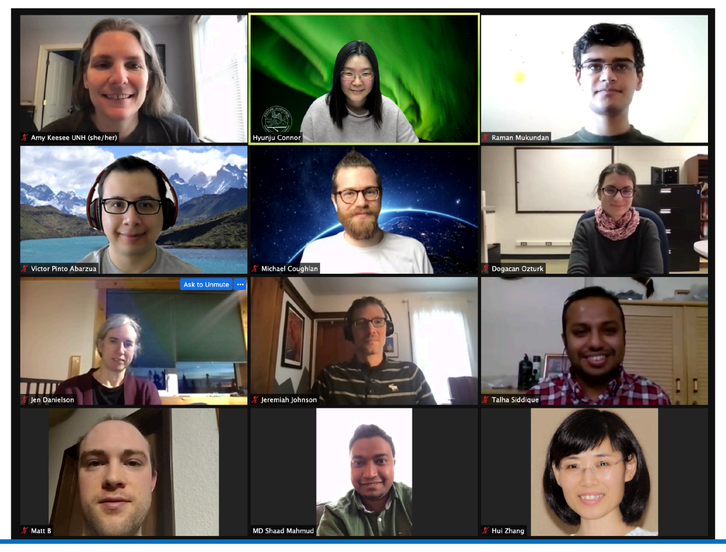
MAGICIAN Team

Machine Learning Algorithms for Geomagnetically Induced Currents in Alaska and New Hampshire

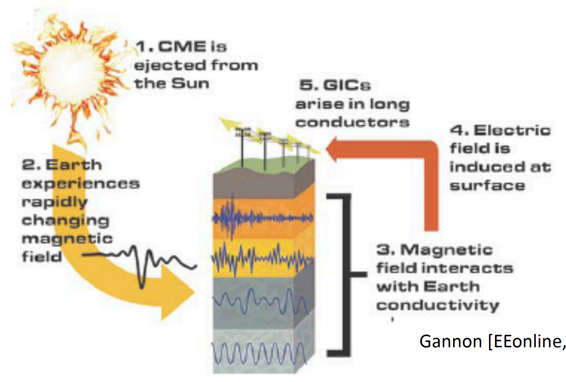
- MAGICIAN is a joint UAF – UNH team funded by the 2018 NSF EPSCoR RII Track 2 Program that develops machine-learning algorithms for predicting hazardous Geomagnetically Induced Currents (GIC).

- Check other presentations of MAGICIAN team at this AI & Data Science Workshop!
  - **Poster #53**: Using an LSTM and Classification Methods to Determine Risk of dB/dt Threshold Crossings as Proxy for Geomagnetically Induced Currents - Michael Coughlan, UNH.
  - **Poster #57:** Comparison of Time Series Techniques to Model Connections Between Solar Wind Input and Geomagnetically Induced Currents - Amy Keesee, UNH.

Meet MAGICIAN Team!



Motivation
Forecast of Geomagnetically Induced Currents (GICs)



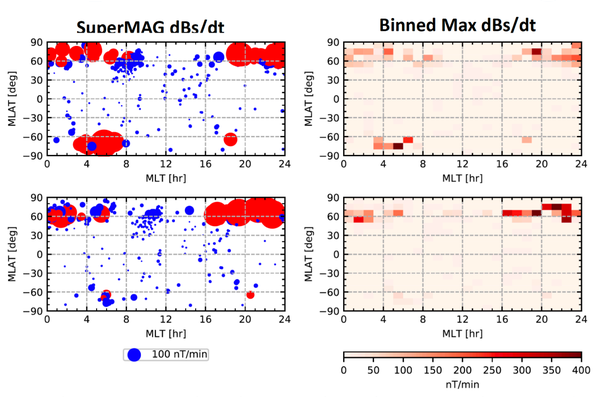
- Worldwide/Nationwide GIC data are not available.
- Our study focuses on the prediction of large geomagnetic field disturbances, a trigger of GICs.

Multi-variate LSTM Model for dB/dt Prediction

Recurrent Neural Network (RNN) for predicting geomagnetic field disturbance (dB/dt)

- DATA:
  - OMNI solar wind and IMF conditions in 2012 and 2015
  - SuperMAG surface & vertical disturbances (i.e., dBs/dt & dBz/dt) in 2012 and 2015
  - 80% for training, 20% for validation, and the 2012-03-09 storm for testing
- Method: Multi-variate Long Short Term Memory (LSTM) network
  - 50 neurons in a single hidden layer, 50 epochs with a batch size of 72
  - Adam's stochastic gradient decent as an optimization algorithm
  - Mean absolute error as a loss function
- Two machines are trained for dBs/dt and dBz/dt predictions.
  - Input: IMF Bz, Solar Wind Density, dBs/dt (or dBz/dt) at a previous minute (t-1)
  - Output: dBs/dt (or dBz/dt) at the next minute (t)

SuperMAG Data Binning

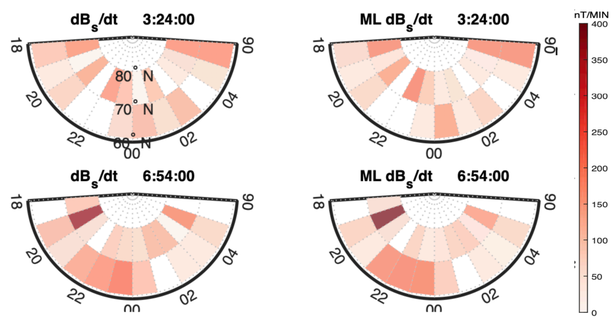


- To provide an even spatial resolution, we binned SuperMAG data into 10° MLAT x 1hr MLT grids and select max dBs/dt and max dBz/dta in each bin as our dataset.
- Red circles indicate potential GIC locations where dB/dt went higher than 100nT/min in the past few hours.

Improvement needed in future

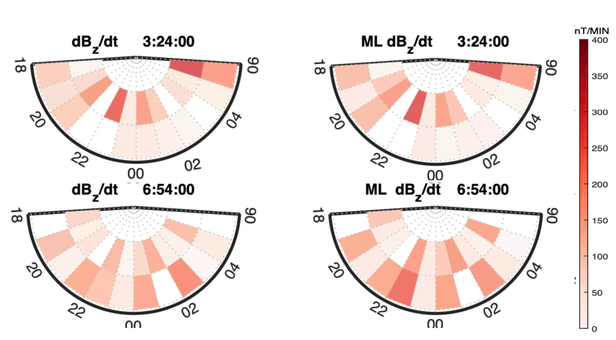
- Train machines with longer periods of data.
- Use a longer time history of input (e.g. 60 mins of SW/IMF data).
- Remove dBs/dt and dBz/dt from the input.
  - Our current model may find stronger correlation with dB/dt at t-1min.
- Consider sophisticated solar wind propagation from the bow shock to each bins.
  - 60min delay from the bow shock to the nightside bins were assumed.
- Consider finer spatial resolution for higher latitude
- Use better validation techniques than RMSE [Welling et al. SW2018; Maimaiti et al. SW2019; Camporeale. JGR 2020]
- Use different machine learning techniques
  - Multi-layered LSTM, Artificial Neural Network, Convolutional Neural Network, Principal Component Analysis, etc.

Model-Data comparison of dBs/dt over the Nightside Northern Hemisphere



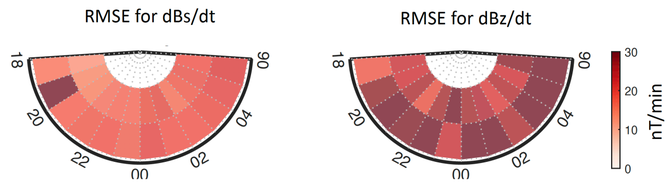
Our machine-learned predictions (right) show a good agreement with the binned SuperMAG data (left) on a larger spatial scale.

Model-Data comparison of dBz/dt over the Nightside Northern Hemisphere



Our machine-learned predictions (right) show a good agreement with the binned SuperMAG data (left) on a larger spatial scale.

Model Results over the Nightside Northern Hemisphere



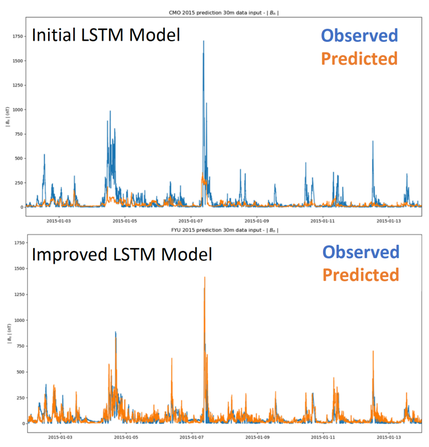
Considering ± 30nT/min of RMSE, our machine may miss or falsely predict ~100nT/min of geomagnetic disturbance.

However, it won't be troublesome to forecast several hundreds nT/min that potentially produces a catastrophic GIC event.

Other MAGICIAN Team Activities

MAGICIAN Team Activity 1: Multi-variate LSTM model for AK array

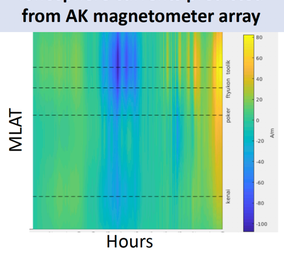
|B| vs time at College, AK



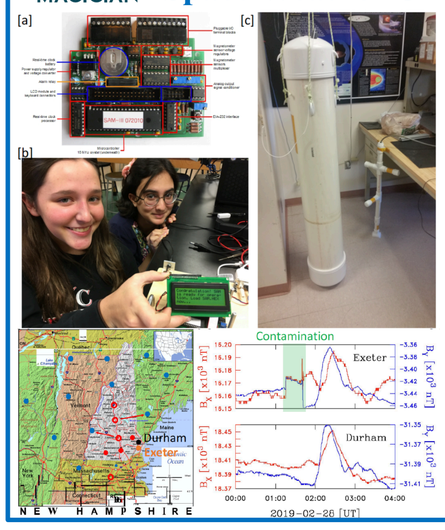
We are developing/improving a LSTM model for the AK magnetometer array by using various input parameters and tuning LSTM parameters/functions.

Once matured, the model can predict the ionospheric currents above AK as well as the GIC risk in AK.

Ionosphere currents predicted from AK magnetometer array

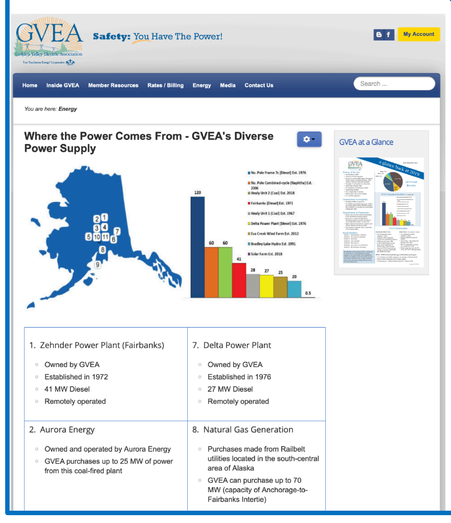


MAGICIAN Team Activity 2: Space Weather UnderGround Project



- UNH SWUG (Chuck Smith, lead) is expanding to UAF (Don Hampton, lead).
- Undergrad and high school students assembles and deploys a low-cost, but research-capable fluxgate magnetometer (1sec and 1nT resolution) across AK and New England.
- MAGICIAN team will gather the magnetometer data in higher spatial resolution and used them for the GIC studies.

MAGICIAN Team Activity 3: Pathfinder GIC Project with GVEA



- Golden Valley Electric Association (GVEA) is the biggest power company in Alaska.
- MOU between UAF and GVEA is on progress to measure GICs for the next 5 years.
- As our first attempt, GIC will be measured at two locations. Multiple candidate locations are currently discussed.
- GIC data will be available to the public.

Summary

- We developed a prototype of a multi-variate LSTM model using 2 years of OMNI and SuperMAG data.
- The prototype model catches over 100nT/min of dB/dt relatively well on 09 Mar 2012 geomagnetic storm.
- Once matured, this model can provide an advanced warning of GICs that are typically triggered by large dB/dt.
- In addition to the ML-GIC models, MAGICIAN team provides the low-cost, research-capable magnetometer arrays in AK and NH, and the GIC measurements in AK to the space science community.

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